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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

Observations of the

EFFECTIVENESS OF CURING CONCRETE PRACTICES FOR PAVEMENTS

by
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Senior Materials and Research Engineer

Presented by

J. W. Trask
Assistant State Highway Engineer
WASHO Conference, Materials Section
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Interest in concrete curing dates back to the early twenties and possibly even earlier as evidenced by published articles about the subject*. Since that time a multitude of articles have appeared. Countless numbers of experiments have been performed, all pointing to essentially the same principles of good curing. Despite overwhelming agreement on the necessity for proper curing of concrete, it is all too often neglected or inadequately performed. In reviewing recent state specifications governing curing of concrete pavements, one is impressed by the amount of space and attention given to the subject. Curing during the first 24 hours is emphasized presumedly because it is felt that this period is the most critical in the development of strong, durable concrete. Reported test data confirm this belief. Curing by wet burlap, cotton mat or impervious paper methods are the most popular as nearly all of the states allow either one or more of these types. Liquid membrane type curing is permitted by only about two-thirds of the states. The remaining third evidently feel that uncertainties in results by membrane curing are greater than can be justified by a moderate reduction in cost. Membrane curing of pavements is permitted and is used almost exclusively in California. My discussion will deal largely with this method.

Before one can compare the effectiveness of concrete curing methods, there must be some understanding of what is to be accomplished. Concrete technologists nearly all agree that at least three things are essential to

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* "Effect of Curing Conditions on Wear and Strength of Concrete" by Duff A. Abrams, September, 1922, reprinted with minor changes from Proceedings, American Railway Engineering Association 20, (1919)

curing concrete; namely, retention of moisture, a favorable temperature level, and time. Without going into the many theories of gel formation, it is sufficient here to say that retention of a quantity of water in excess of that required for chemical combination with the cement is necessary to assure adequate curing. This is because the products of the hydration process can be formed only in water-filled capillaries within the concrete. In general then, essentially the entire amount of mixing water should be retained in the concrete during the period of formal curing. Specifications are written with the intention of maintaining such a level of moisture during this period.

It is important to recognize that concrete curing compounds do not completely prevent the loss of moisture in vapor form from concrete. For slabs laid on the ground, the rate of loss of moisture through the applied membrane tends to be compensated by the absorption of moisture by the concrete from the subgrade. This appears to be the case even though a pavement is placed on a cement-treated base with bituminous seal. The permeability of asphalt films to water vapor is comparable to that of the membrane formed by concrete curing compounds.

For structures, the situation is radically different because intimate contact with the natural ground is not usually provided. There is no way in which evaporation through the membrane can be made up by absorption from other sources. In California, wet curing methods are specified for bridge decks.

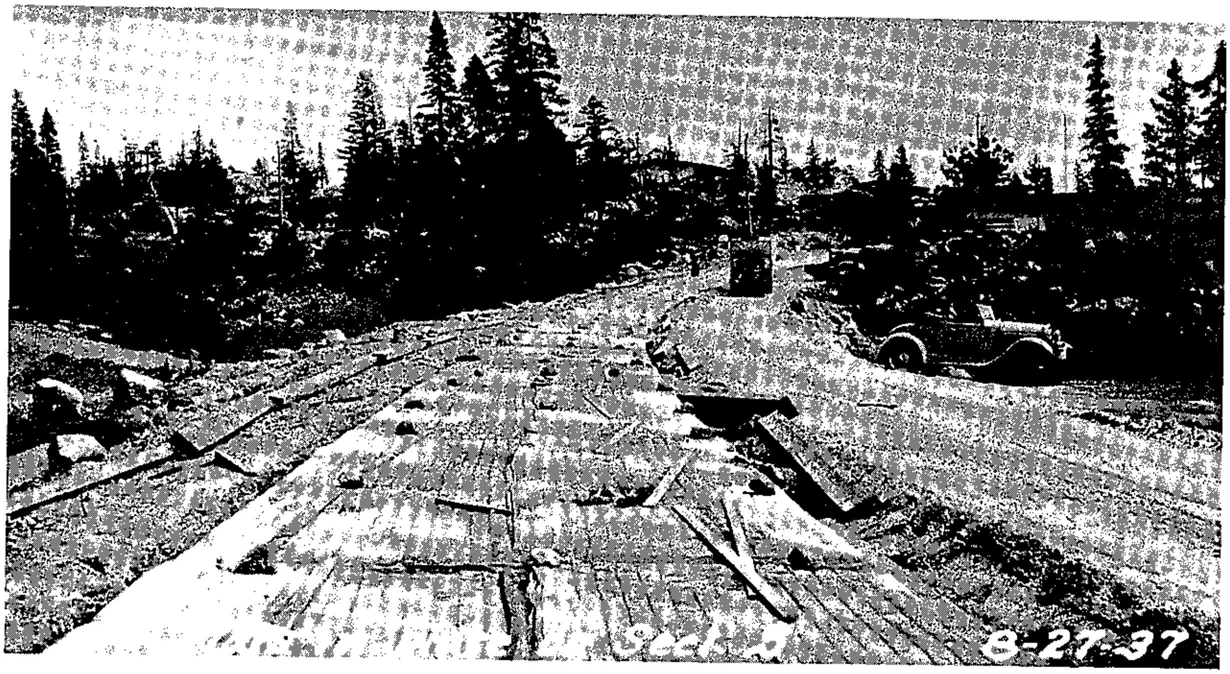
The second requirement, temperature, is also provided for in most specifications but with general emphasis on maintaining sufficient warmth during cold weather. The problem of keeping concrete pavement temperatures down during hot weather is not covered as well, but it is an important one, especially here in the West where maximum temperatures tend to be high.

Membrane curing is conducive to the development of high pavement temperatures during the day and rapid cooling at night. As a consequence, random cracking ahead of joint sawing becomes a problem. This condition has been alleviated greatly by the simple but somewhat costly application of a fog spray to the pavement surface after the membrane has been applied and has set. To obtain effective cooling by the evaporation of water, it is necessary that the applications be made at

frequent intervals. The application of burlap or other mats will permit less frequent watering and hence will simplify the problems of inspection. A preliminary 24-hour cure with wet burlap is specified by many agencies. The method is most effective on pavement placed in the morning as the highest pavement temperatures occur in that portion of the day's placement.

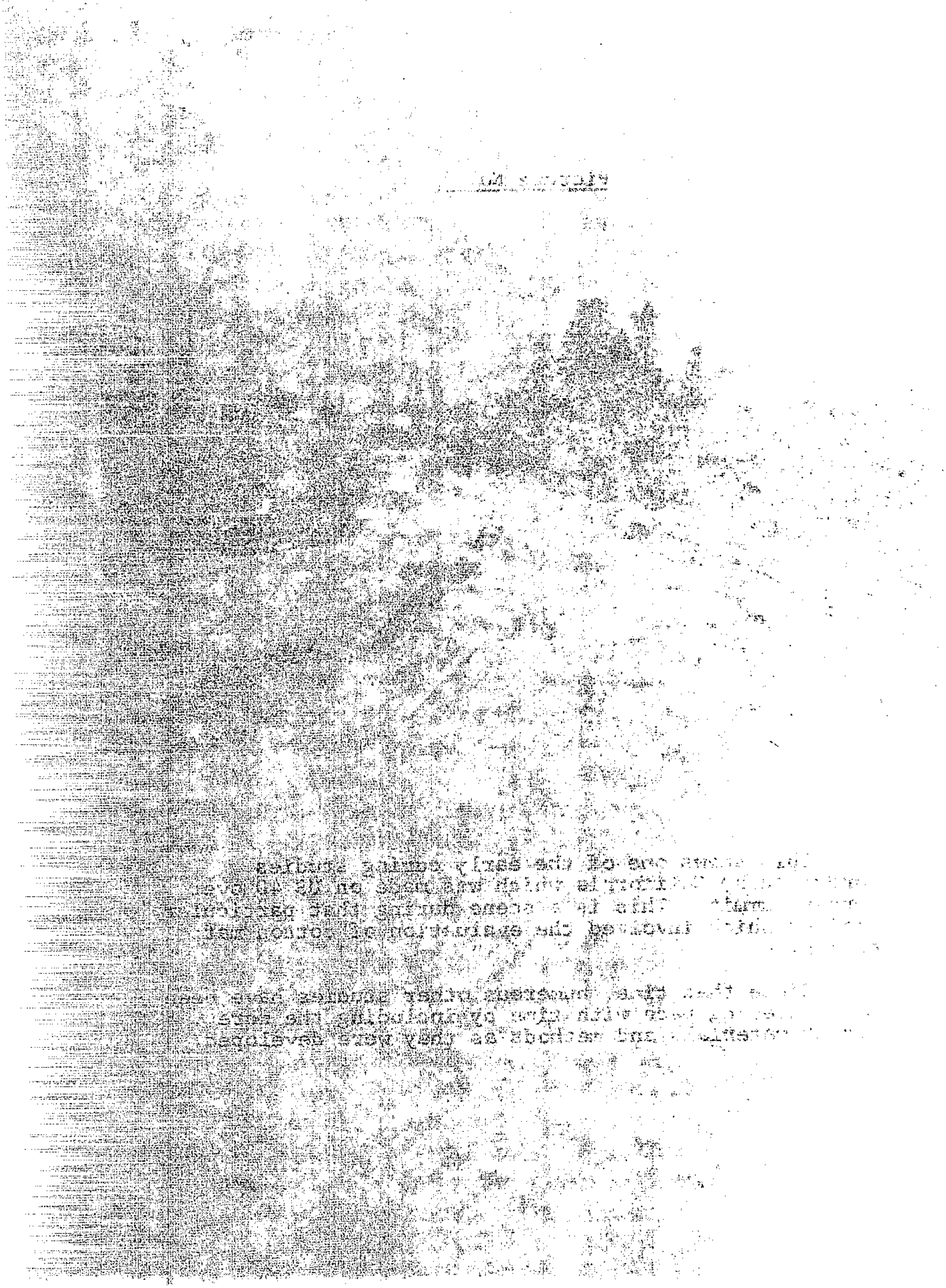
In the early days, it was customary to require formal curing at least ten days. Probably this was a necessary requirement because of the relatively slow rate of hardening provided by the coarsely ground cements of that period. In recent years cements are ground more finely and they hydrate at a faster rate. The result has been a shortening of the length of time required for the greater part of the hydration to take place. This has been reflected in current specifications for curing which almost universally permit curing to be discontinued after 72 hours. Although 72 hours of formal curing may present an economical balance, the tendency exists in some quarters to ignore the possibility of damage to curing membranes during this brief period. It should be recognized that the rather fragile film can easily be broken by foot or vehicular traffic and that such damage can occur at points of greatest vulnerability to future ravelling under traffic.

Picture No. 1

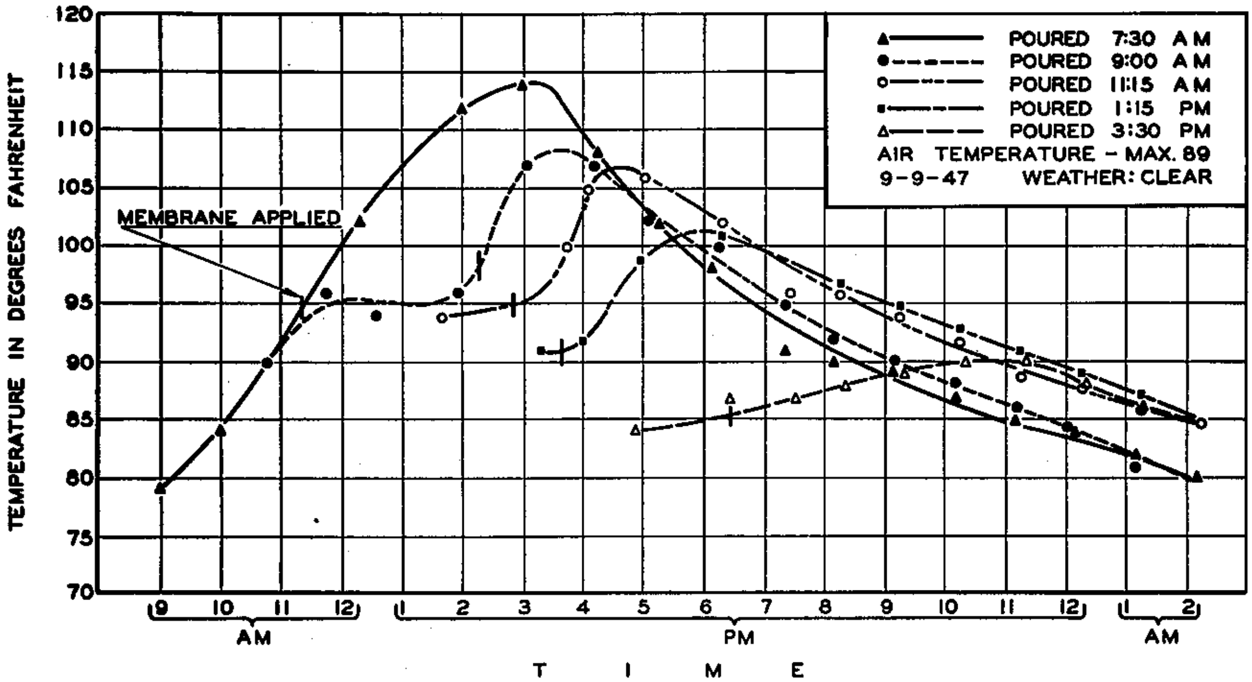


This shows one of the early curing studies conducted by California which was made on US 40 over Donner Summit. This is a scene during that particular project which involved the evaluation of cotton mat curing.

Since that time, numerous other studies have been made, keeping pace with time by including the more recent materials and methods as they were developed.



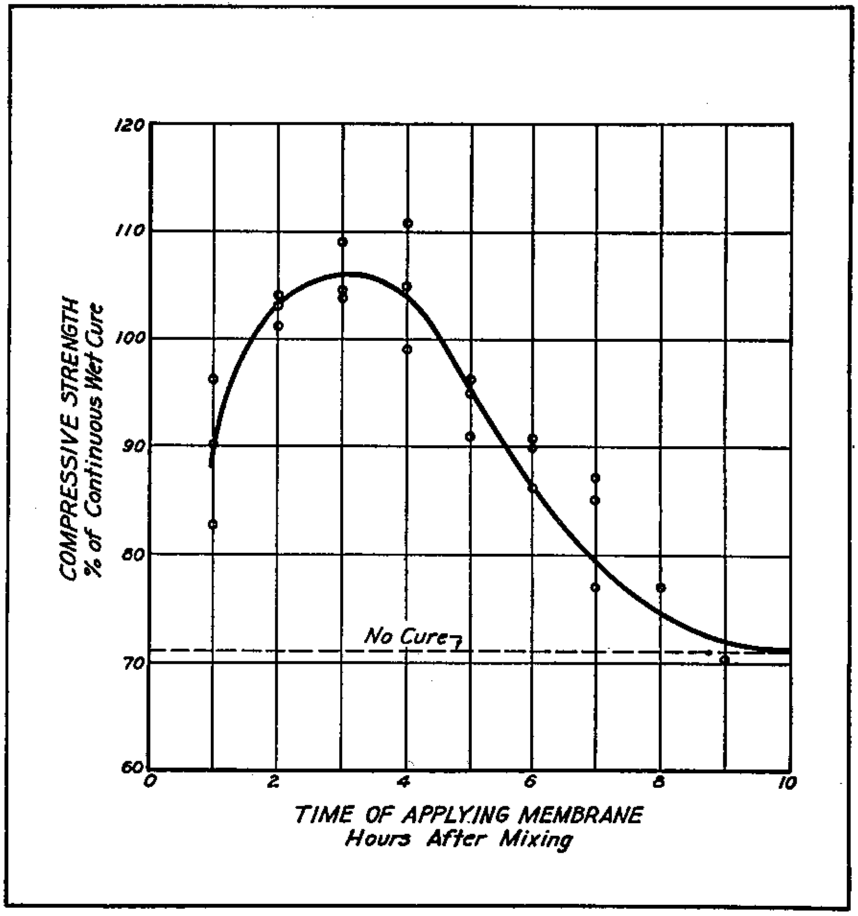
Picture No. 2



Surface temperatures of pavement slabs poured at different times of the day.

Picture No. 2 is a graph taken from a report on curing studies made by the Michigan Engineering Experiment Station in 1949. It shows the effect of curing compound on pavement temperature. Note the first and second curves from the left. The evaporation of water from the surface of the pavement kept the temperature down until the curing membrane was applied at 2:15 p.m. as shown in the second curve. Then the temperature immediately began to rise. While cooler temperatures are beneficial to concrete, the effect of the loss of water from the concrete at an early age can result in shrinkage cracking and poor surface quality and therefore should be avoided.

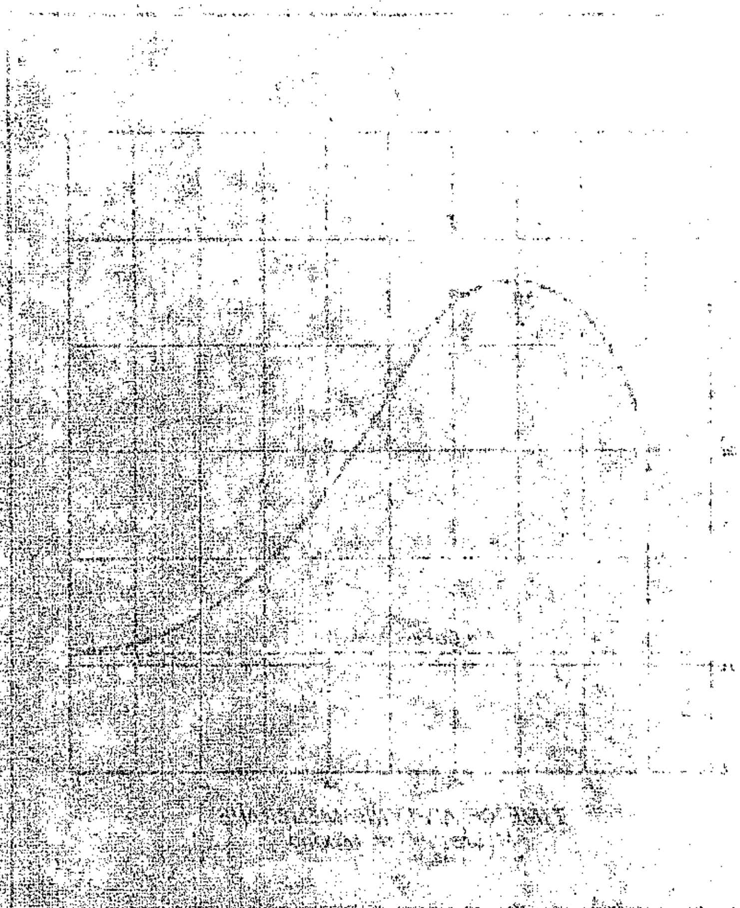
Picture No. 3



★ Strength is highest when curing is started at optimum time

Picture No. 3 shows that compressive strengths greater than under continuous water cure were obtained when the compound was applied about 3 hours after mixing. This time was the optimum for the particular weather conditions during the test. Other conditions and perhaps such things as bleeding characteristics of the concrete can affect the optimum time for applying membrane. It is important to note that there can be adverse effects from applying it either too soon or too late.

If applied while bleeding water is still rising to the surface, the formation of a continuous membrane may not be achieved. If applied after surface water has disappeared, capillaries which have formed in the cement paste structure will have been partially emptied, increasing the area of exposed concrete several fold. The curing compound under such conditions will enter the capillaries, leaving an insufficient amount to cover the remaining surface. The result is a film of inadequate thickness to prevent excessive loss of water in vapor form.



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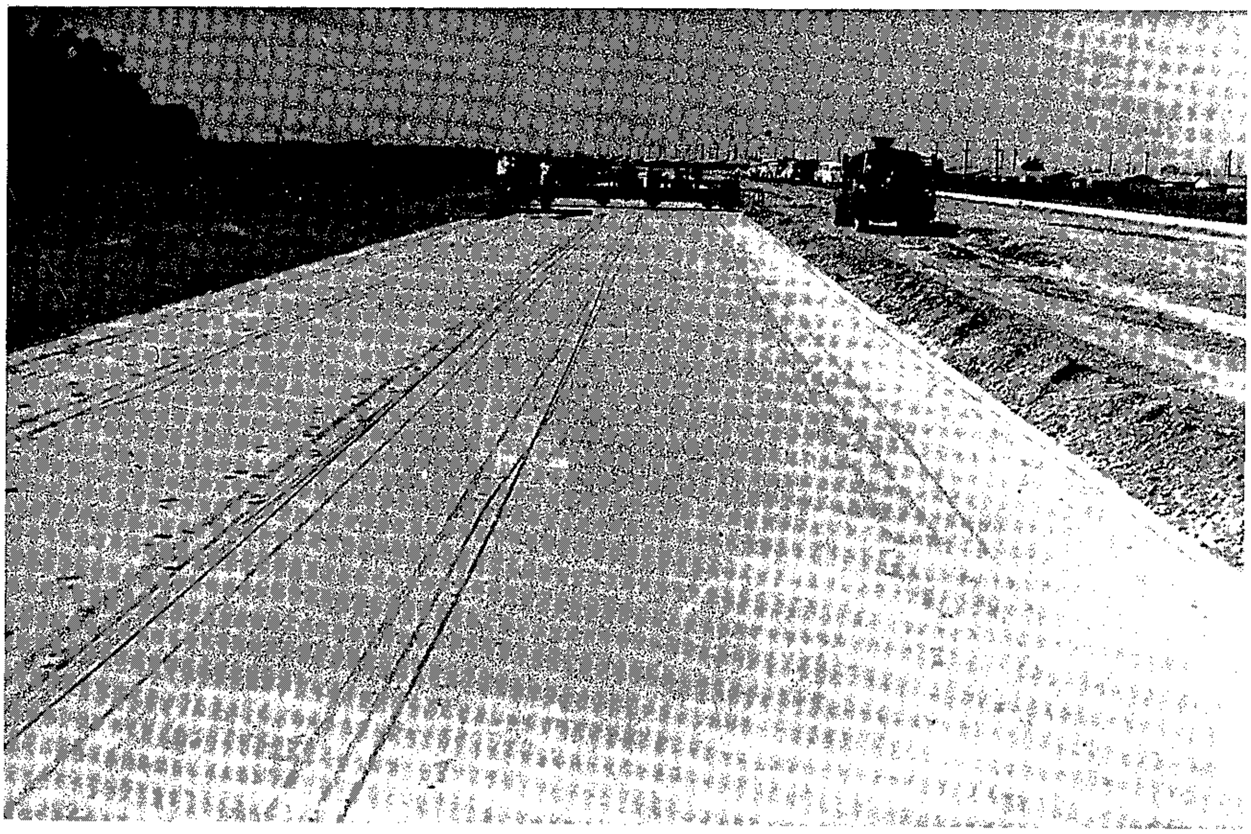
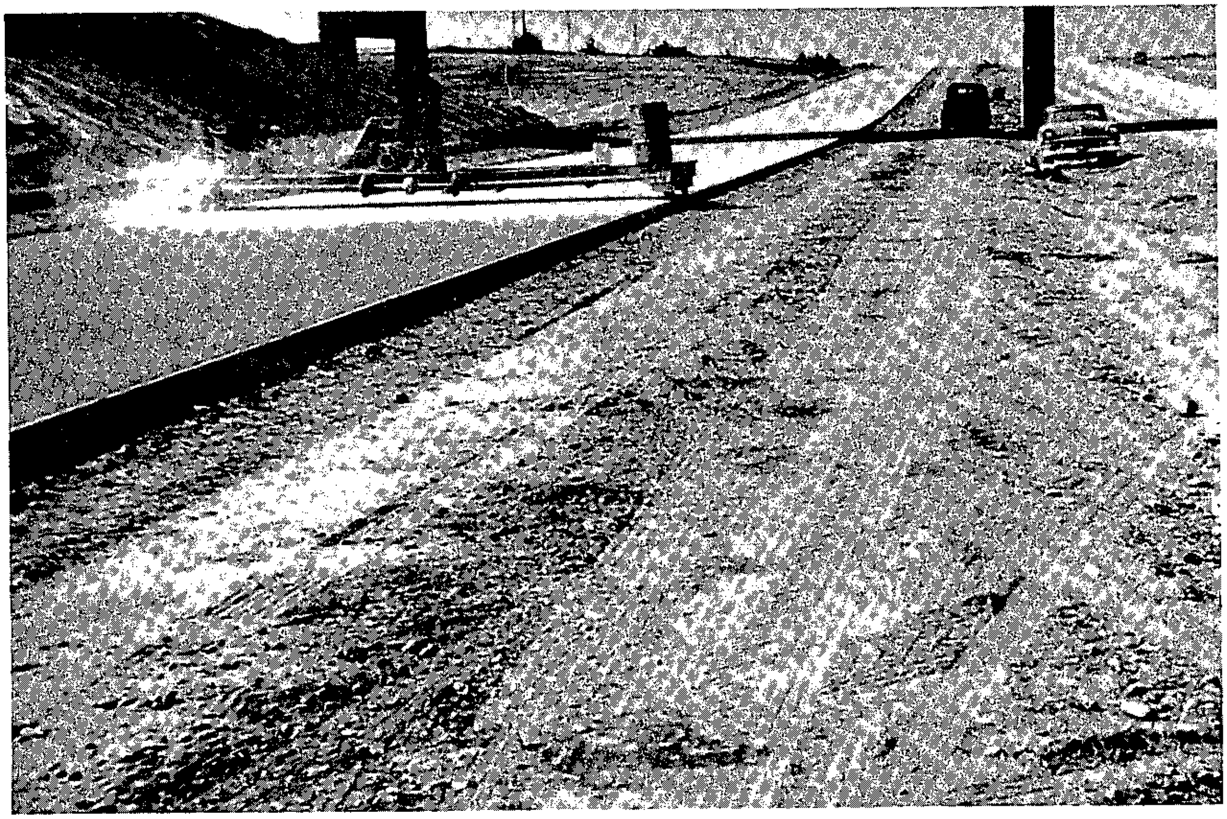
Picture No. 4



Picture No. 4 shows damage to the curing membrane which has been caused by wheeled traffic and foot traffic. In such cases the effectiveness of the seal is greatly reduced and it should be restored by again spraying the areas with curing compound.

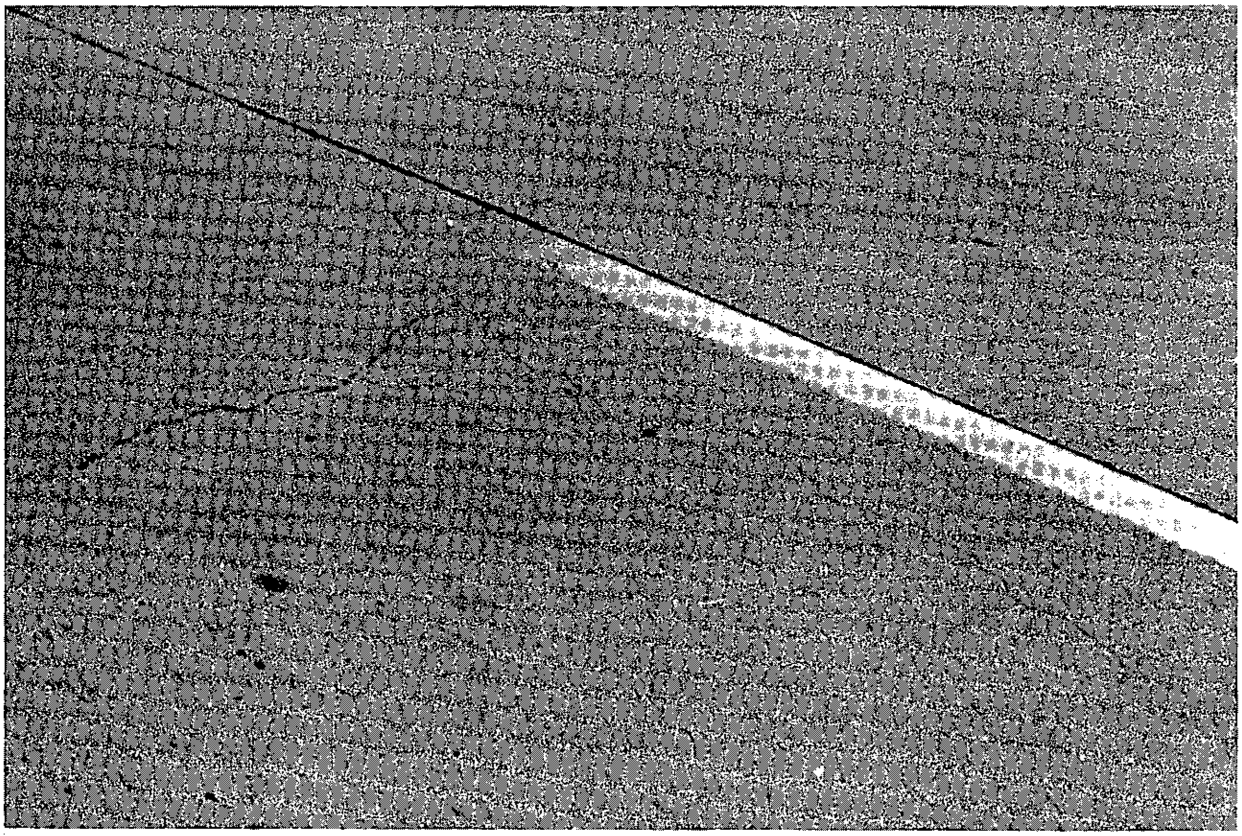
Picture No. 5



In the past the application of curing compounds has been accomplished by hand spraying. Under adverse conditions such as high cross winds, a substantial amount did not reach the pavement. The result was insufficient coverage for the conditions, which in turn caused cracking of the pavement. When the rate of application was increased, the cracking was greatly reduced. California's new specifications require mechanical application with the use of hoods over the nozzles to insure even coverage with a minimum loss of compound.

The necessity of adequate shielding for spraying operations is shown in this picture. The rate of application as determined by ideal conditions, would have to be increased under the conditions shown if an adequate coverage is to be achieved.

Picture No. 6



Picture No. 6 shows some of the cracking which has occurred in portland cement concrete pavement only a few days old. The cause was attributed to shrinkage at an early age due to loss of water. The application of more curing liquid membrane greatly reduced the amount of cracking.

Sawed joints in pavements present a particular problem. Not only is the surface film subjected to abrasion, but new uncoated faces are formed in the sides of the groove. These are difficult to coat with membrane, yet the pavement in the vicinity of the cut is the most vulnerable to spalling under traffic.

If the joints are to be sealed with some type of permanent compound, prompt installation after sawing is an effective means of promoting good subsequent curing. If the joints are not to be sealed with joint compound, the problem of providing adequate curing is a difficult one. Although California has experimented with many types of pavement joints, none can be said to be fully satisfactory. Failure to secure good curing at joint faces is one of the causes of unsatisfactory results.

It is interesting to note that as a general rule, the best curing methods as determined by early tests are still proving to be superior and that present methods tend to be compromises in an effort to balance cost with effectiveness. While strength has been most often used to judge effectiveness, more and more attention is being given to factors such as durability (resistance to physical and chemical attack), volume changes inducing cracking, and curling tendencies.

Concrete becomes much less permeable with age if curing water is available. Reduced permeability means greater resistance to penetration by de-icing chemicals and also to penetration by carbon dioxide from the atmosphere. Carbonation to appreciable depth is responsible for shrinkage over and above that produced by loss of moisture. In general, it may be said that carbonation is responsible for the crazing so often seen in residential slabs where little attention has been paid to curing. A close examination of highway pavements reveals that they are not universally free from crazing resulting from surface carbonation.

In evaluating the effectiveness of curing, visual observation is helpful but is necessarily biased because of personal factors. Certainly there is a lack of the type of information needed to relate performance to weather conditions, especially during the first few days after placement. It is difficult to determine the relative effects of wind, heat, humidity and bleeding characteristics of the concrete, when these are present in different degrees from one day to the next and even one hour to the next.

Differences in strength resulting from differences in curing procedures tend to disappear with time, but this does not mean that good curing is not important. Regardless of how strong the concrete may eventually become, its utility as a pavement or structure may be seriously impaired by neglect of early formal curing. Nearly all properties except ultimate strength are enhanced by good curing practices.